DOCUMENT RESUME

ED 191 661 SE 031 627

AUTHOR	Tanner, C. B.
TITLE	Course in Biometeorological Field Techniques. Final Report to National Science Foundation.
INSTITUTION	Wisconsin Univ., Madison.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	Dec 75
GRANT	NSF-GZ-1369
NOTE	24p.
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	College Science: Course Descriptions: Higher Education: *Light: *Meteorology: *Science Curriculum: Science Education: *Solar Radiation: *Teaching Methods: Training Methods

ABSTRACT

This is the final report to the National Science Foundation (NSF) from a grant to develop a course in biometeorological field techniques. Objectives of the course were to give students experiences in making field measurements of parameters of the physical environment and their impact on plants and animals: and to develop an understanding of the basic principles of transducers, data logging equipment, and modification of transducers for particular measurements. Another objective of the project was to make available instrumentation to several universities so that field techniques courses could be initiated immediately without a large initial investment in equipment. The course was planned to provide "hands-on" experience with field measurements of biologists, engineers and meteorologists, and to teach some of the fundamentals of instrumentation. The success of the project was mixed in that the number of students receiving "hands-on" experience was low but the students who did participate did receive good in-depth experience and training. (Author/DS)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

GZ-1369(B2)

RECD JAN 2 1976

Archives of
HIGHER EDUCATION IN SCIENCE
ATP SCIP MIDS

Property of
THE NATIONAL SCIENCE FOUNDATION

ED191661

FINAL REPORT

TO

NATIONAL SCIENCE FOUNDATION

FOR

NSF GRANT NO. GZ-1369

UW ACCT NO. 144-9944

COURSE IN BIOMETEOROLOGICAL FIELD TECHNIQUES

Report Period: 1 July 1969 through 30 November 1975

Report submitted 31 December 1975

Submitted to: Alice P. Withrow, Program Manager
Alternatives in Higher Education
Materials and Instruction Development Section
Div. of Higher Education in Science
National Science Foundation
Washington, D. C. 20550

Submitted by: C. B. Tanner, Principal Investigator
Professor of Soils and Meteorology
Department of Soil Science
1525 Observatory Drive
University of Wisconsin
Madison, Wisconsin 53706

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Mary L. Charles
of the NSF
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Outline

	Page
Resume of program	1
Objectives	1
Background	2
Training	3
Approach	3
Formal courses offered	4
Other equipment uses	6
Summary	7
Future plans	8
Expenditures and equipment	9
Appendix A: Ohio course	11
Appendix B: Report 9/30/74 to 9/30/75	19

Resume of Program

Objectives

1. To give students experience in making field measurements of parameters of the physical environment, their impact on plants and animals, and to develop an understanding of the basic principles of the transducers, data logging equipment and modification of transducers for particular measurements.

2. To make available instrumentation to several Universities so that field techniques courses could be initiated immediately without large initial investment in equipment (we assumed that equipment and training programs could then be built up and consolidated by the Universities from local funding).

Background

During the period of 1963 to 1969, a graduate educational program in biometeorology was sponsored by the National Air Pollution Control Administration within the eleven CIC universities.* During this time, we found no university courses directed to training students in field biometeorological measurements and instrumentation. The CIC Biometeorology Committee, with members drawn from many disciplines in the eleven universities, believed that a course filling this need would be valuable, not only to the students actively participating in the CIC Graduate Biometeorology Program, but also to other students with biometeorological interests, such as ecologists. Accordingly, in 1967 the program purchased a mobile laboratory ($6100) and some equipment ($21,500) in an effort to establish a mobile facility that could be moved to different biological field stations and serve as a major resource for instruction of biometeorological field techniques. No funding to complete equipping the mobile laboratory and to operate it was available following 1968, and we requested support from NSF to initiate the field techniques course. The course was planned to run in conjunction with field programs of Universities, such as those at biological stations; it was to rely on local staff leading the courses and continuing them.

The NSF provided funding (NSF Grant GZ-3169) as of July 1, 1969 to complete equipping the mobile laboratory and to operate it through a termination date of November 30, 1971. The mobile laboratory was placed into operation in the summer of 1969. The "host" institutions were interested in extending use of the facility as much as possible and provided some salary for professional personnel, some

* Committee on Institutional Cooperation of the Council of Ten and the University of Chicago; a consortium of eleven Midwest universities.

housing and food for the personnel, and some moving expenses. The Department of Soil Science also provided some technician service for maintenance of equipment. Because of these economies, in 1971 we requested an extension of termination date, without additional funding, to November 30, 1974. In 1973, the project was extended a second time to November 30, 1975.

Training

Approach

The course was planned to provide "hands-on" experience with field measurements for biologists, engineers and meteorologists, and to teach some of the fundamentals of the instrumentation. Engineers and meteorologists need to become acquainted with living systems and the specialized modifications of instruments needed for their measurement; biologists need to understand better instrumentation principles and how transducers interact with the organism. This learning experience is most easily accomplished at biological field stations where ancillary staff and instruction also is available.

For purposes of instruction, measurements (instruments) were classified according to physical parameters as listed below; however, a learning experience, such as measuring the energy balance of a leaf, would involve every class of measurement. The measurements considered were:

A. Radiation flux, principles and measurement

1. Solar radiation (pyranometers)
2. Total radiation
3. Net radiation
4. Thermal radiation (including IR thermometry)
5. Spectral distribution of light
6. Foot-candle meters and photopic response
7. Photosynthetic light

B. Thermometry principles and use

1. Thermocouples (kinds, references, read-out)
2. Thermistors (kinds, linearization, matching and stabilizing bridges)
3. Resistance wire thermometers (kinds, bridges)
4. Diodes (kinds, bridges)
5. Calibration (heating, cooling, phase-point, comparison)
6. Radiation and conduction errors

C. Humidity

1. Psychrometers (wet and dry bulb thermometers)
2. Dunmore element (conductive gels)
3. Surface adsorption elements
4. Calibration

D. Wind

1. Cup anemometry
2. Wind profile measurement
3. Heat transfer anemometry (low air speed)
4. Turbulence

E. Biological

1. Biological water potential
2. Stomatal diffusion resistance
3. Microscopy
4. Oxygen, ozone
5. Oven, balances, binoculars, and other miscellaneous

The above measurements all involve power sources (batteries, inverters, engine generators) and various types of data-logging and processing equipment (recorders, amplifiers, integrators, portable calculators); in fact, the greatest demand was for data-logging equipment since all the above measurements required it. Instruction on data-logging and on power supplies were essential.

Standard texts and journal articles were relied on for background reading and mimeo handouts on special topics were supplied as needed.

Formal courses offered

The mobile laboratory and equipment have been used in summer training courses from 1969 through 1973; it has also been used during the school year three times for formal

course offerings that involved "hands-on" training. Arrangements for the use of the mobile laboratory during the summers of 1974 and 1975 fell through because of program cuts at the host institution. This was due to unexpected loss of staff with necessary background and interest.

The mobile laboratory has been used in formal training courses as follows:

Date	Institution	Place Headquartered
Summer 1969	Ohio State Univ.	Bass Island Biological Station
Sept. 1969-May 1970	Ohio State Univ.	Columbus campus
Summer 1970	Univ. of Michigan	Douglas Lake Biological Station
Summer 1971	Univ. of Minnesota	Lake Itasca Biological Station
Summer 1972	Univ. of Michigan	Douglas Lake Biological Station
Aug. thru Dec. 1972	Ohio State Univ.	Columbus campus
Summer 1973	Univ. of Minnesota	Lake Itasca Biological Station
Aug. thru Dec. 1974	Ohio State Univ.	Columbus campus

Detailed descriptions of each of the courses have been outlined in our annual reports and will not be repeated here. In the eight formal summer courses a total of 108 students have registered. Of these students, 87 have been in graduate training and 27 have been upper division undergraduates; 79 have been in biology (botany, zoology, agronomy), 23 in earth science (geography, geology, meteorology, soils) and 6 have been in engineering and physics.

Although the number of students has been less than we anticipated, partly because plans for the 1974 and 1975 summer offerings failed, there has been in-depth use of the equipment. This is indicated by the student-hours use

tabulated below. It should be noted that these student-hour data are underestimates, since close logging was impractical; also, any student-hour may represent use of one to six items of a given equipment use during that period.

Class of Equipment	Student-hours
Radiation	1,121
Thermometry	1,118
Humidity	631
Wind	389
Biological and misc.	1,270
Subtotal	4,529
Data-logging and processing and power sources	5,978
TOTAL	10,507

The above illustrates the heavy duty on data-logging equipment, particularly since some of the biological equipment requires no data-logging facilities. Part of the use of data-logging equipment was in conjunction with University-owned instruments.

Other equipment use

The equipment in the mobile laboratory has had use by graduate students who were not registered in courses for formal instruction. Virtually all of this has been for graduate research on biological problems. Equipment also has been used in some ecology and meteorology instruction.

Records on equipment loan have not been as systematic as they should have been, except when the mobile laboratory was at a biological station with supervising staff in constant attendance. Records of loans, except at biological stations, also do not give reliable data on usage because instruments usually are not in active use the entire period of the loan. Despite these inaccuracies, we have listed

below some of the uses. As before, any use-time normally represents several instruments.

Use at Biological Stations (all classes of instruments)	2,110 student hours

Loaned for extended periods of thesis research	Student-week
Radiation	208
Temperature	49
Humidity	14
Wind	240
Biological (mainly water potential)	256

While most of the above use has been by students on the University of Wisconsin-Madison campus during periods when the mobile laboratory was not used for formal instruction, equipment has been loaned to a CIC physiology student at Minnesota, an environmental science student at UW-Milwaukee, and a Peace Corps participant in Malaysia.

Summary

Our success in meeting the original objectives of the program is mixed. The number of students receiving "hands-on" field experience (108) is lower than desired, and would have been still lower if we had not operated under a 4-year extension. The fact that the anticipated use during the summers of 1974 and 1975 was not realized, contributed. The main users for formal instruction have been only three universities with active summer programs at formal biological stations or with field facilities near campuses, and this decreased our flexability in assuring summer course offerings. On the other hand, the students who participated did receive good, in-depth experience and training.

The results in fostering biometeorological techniques courses in universities also are mixed. Of the three main user universities, Michigan and Ohio have made considerable

advance. Michigan has completed installation of a quality climate facility at Douglas Lake, and offers excellent training; however, Director David Gates would have achieved this end, with or without use of our facility. On the other hand, the facility provided the impetus for Ohio to establish a techniques course. Ohio has initiated a microclimate course and committed about $12,000 to instrumentation to its operation (Appendix A).

Future Plans

The University of Wisconsin-Madison has had no formal biological field station courses in the past and presently anticipates none. Accordingly our emphasis in the field techniques facility has been to support programs at other more suitable sites. However, we will now offer during the spring semester each year, a laboratory-glasshouse course in which principles of plant environment measurement is discussed and hands-on experience gained. This graduate course "Topics in the Physics of the Soil-Plant Environment" (1 credit) will consist of three laboratory hours weekly. Some commonly used measurements will be offered each spring; however, other measurements will be changed according to student interest. This spring we will be working with measurement of soil, air, and plant temperature; stomatal diffusion resistance; plant water potential; and vapor pressure difference.

We intend to continue a policy of loaning equipment. The requests for equipment on the Madison campus have increased greatly the past year, and we hope to meet this demand as much as possible, both for thesis research and course instruction.

Insofar as practicable, in view of transportation and maintenance difficulties, we would like to continue support at Ohio while they continue to implement their new course (Appendix A).

We have had verbal inquiry from Indiana University. Since both Ohio, Indiana, and Wisconsin are CIC Institutions, we are hopeful interuniversity loan will be facilitated.

Expenditures and Equipment

The budget allocations approved for our grant January 4, 1974 (amendment No. 1) are listed below, together with actual expenditures from the grant. Some of the equipment purchases were divided between NSF and the University of Wisconsin. We have listed the University of Wisconsin contribution as well.

Category	NSF Grant GZ-1369 Budget	NSF Grant GZ-1369 Expenditure	Univ. Wis. Expenditure
Salaries	$19,000	$18,865.26	$ 2,500##
Equipment	31,500#	34,305.53	9,993
Travel & per diem expense	4,900	3,404.17	
Maintenance & operations			
a) Supplies	4,200	4,216.25*	
b) Services	5,110	5,130.79	
Subtotal	$64,710	$65,922.00	$12,493
Indirect costs	5,955	4,742.47	
TOTAL	$70,665	$70,664.47	$12,493

Permission given 10 Oct. 1975 to use an additional $1,500 toward an 8K memory, would give $33,000 approved for equipment.

* Includes $66.75 for reference books classed as "Other Capital" in UW Accounting System.

Estimated 2.5 months salary of technician donated for equipment maintenance and transportation of mobile laboratory to and from location and setting up.

Equipment

The expenditures for equipment by classes are as follows.

Equipment class	Expenditures (Rounded) NSF	U.W.
Radiation	$ 3,196	$
Thermometry	344	
Humidity	3,602	345
Wind	128	
Biological and misc.	8,352	1,278
Power sources	757	
Data logging and processing	13,864	8,370
References, biases, bridges, calibration: ancillary to use of instruments	1,302	
Maintenance equipment; standards, meters, test equipment, tools	2,761	
TOTAL	$34,306	$9,993

In addition to the $9,993 supplemented by the University of Wisconsin, as mentioned on page 2, a mobile laboratory valued at $6,100 and equipment valued at $21,500 were established by the University of Wisconsin for this techniques course at the time NSF support was sought.

APPENDIX A

THE OHIO STATE UNIVERSITY

December 10, 1975

Professor C. B. Tanner
Department of Soil Science
1525 Observatory Drive
University of Wisconsin - Madison
Madison, Wisconsin 53706

Dear Champ:

This letter outlines the benefits which I feel The Ohio State University has derived over the last seven years from the use of the NSF Mobile Field Training Laboratory. I support strongly any effort to maintain this facility so that we might use it in the future and so that other institutions can build programs on it as we have done.

The Ohio State University used the Mobile Laboratory first in 1969 when Professor Gareth Gilbert of Botany taught a summer course at the Stone Laboratory in Lake Erie. This was followed by an autumn quarter course on the Main Campus given by Professors G. Gilbert (Botany) and John N. Rayner (Geography). In autumuns 1972 and 1974 the Mobile laboratory was again transported to Ohio State for the basis of courses given by Professors John N. Rayner and A. John Arnfield, both of Geography. Some of the benefits of the availability of the equipment are listed below:

1. It demonstrated a need on the OSU campus for a practical course in environmental measurements.

2. It permitted the faculty to gain experience and to develop a well structured course on measurements.

3. It gave practical training to nearly 50 students in a variety of disciplines, which included agronomy, botany, geography, geology, natural resources, physics and zoology.

4. It provided good publicity to the subdiscipline of microclimatology.

5. It resulted in the granting of some $12,000 by the College of Social and Behavioral Sciences for the purchase by the Department of Geography of some of its own equipment.

College of Social & Behavioral Sciences / Department of Geography / 1775 College Road / Columbus, Ohio 43210 / Phone (614) 422-2514

6. This has culminated in the development of a formal course proposal so that a practical measurements course will be given on a permanent basis (outline attached).

As you are aware, $12,000 does not go far with equipment these days. Consequently, we would like to use the following items in the future if they be available:

Trailer
Eppley Pyranometer
Kipp Solarimeter
ESI Portametric Voltmeter Bridge
Wind Profile System
Mosely shipchart recorders
Rustrak recorders
Roysen Lectrocount II integrator
Barnes IR Thermometer
Assmann psychrometer
Honeywell dewprobe
Simpson meters
YSI Thermometer System
YSI Dew Point Hygrometer
Funk net radiometers
Heat gun
Nanovolt Source
ISCO Spectroradiometer
Various demonstration thermometer sets and millivolt sources.

Of course, we recognize that this will entail some cost to us. In the past we have always insured the Laboratory and its contents and have partially supported the transportation costs.

It is clear that this aspect of the Biometeorology Program of CIC has been highly successful. I have had several enquiries from other institutions about the availability of this equipment and a past student of mine, Dr. Jerry Davis, of the Department of Geography at Indiana University, is investigating the possibility of developing a course based on the equipment were it maintained.

In conclusion, thank you, Champ, for all of your assistance. I shall follow closely your attempts to keep the Laboratory in existence.

Sincerely,

John N. Rayner
Chairman and Professor

JNR:taa
Enclosures

Geography 622.02 Microclimatological Measurements

Introduction

This practical course has been taught jointly three times before under a 694 number. It was based upon equipment loaned to The Ohio State University from the C.I.C. (Committee on Institutional Cooperation, i.e. Big Ten plus Chicago) Biometeorology Graduate Program. Then, as now, it has provided practical experience in the theory, fabrication and use of instruments for the measurement of micrometeorological variables for students in such diverse fields as botany, agronomy, electrical engineering, zoology, polar studies and geography. The faculty involved were Professor Gareth E. Gilbert (Botany) and Professor John N. Rayner (Geography) in Autumn 1969, and both Professors John N. Rayner (Geography) and A. John Arnfield (Geography) in Autumn quarters 1972 and 1974. Because of limited supplies of equipment and space the enrolment was restricted. In each of past offerings the course enrollment was 12, 15 and 11 respectively.

The proposed course is based upon instruments and equipment, which have been acquired by the Department of Geography over the last three years. During that time a manual has been prepared by Professors Arnfield and Rayner and this will supplement the standard texts.

Objectives

To give students who are interested in the lower atmosphere practical experience in:

a) planning a measurement program for a specific problem;

b) operating electronic recorders, such as Hewlett-Packard strip chart recorders and Esterline Angus data systems;

c) fabricating sensors such as, thermocouples, thermopiles and psychrometers;

d) setting up single sensors and systems of sensors in the field situation; and,

e) completing initial analyses of sensor output.

Outline

1. Measurement: Role of measurement-sampling (space and time) response, calibration, statistical summary.
2. Electricity: Elementary theory and simple circuitry, power supplies, characteristicsof various recording devices.
3. Temperature: Its relationship to heat, problems of air temperature measurement, sensor types, fabrication of thermocouples, thermopiles, field installation of sensors.
4. Radiation: Fundamental physics, solar and terrestrial flux, sensor types and their characteristics, calibration in short and long-wave regions, sensor exposure, radiometry in plant stands. Infra-red thermometry.
5. Humidity: Theory of measurements, building of an humidity profile system.
6. Wind and turbulent transfers: Geostrophic flow, laminar and turbulent flow, wind profiles, measurement.
7. Fluxes. Conduction. Methods of measurement and estimation of the energy and massfluxes in the lower atmosphere.

Tanner, C. B., 1963: Basic instrumentation and measurements for plant environment and micrometeorology. Soils Bulletin, 6. University of Wisconsin. OSU Library call # QC876T23, 1963a.

Latimer, J. L., 1972: Radiation measurement. International Field Year of the Great Lakes Manual.

Slatyer, R. O. and I. C. McIlroy, 1961: Practical micrometeorology. Unesco. OSU Library Call # QC982.7 S5.

World Meteorological Organization, 1971: Guide to Meteorological Instrument and Observing Practices. Geneva, W.M.O. OSU Library # QC871W6 1971

Various instrument manuals and journal papers. (Full reading list is several pages long.)

CAMPUS On

17

October 27, 1975 Volume 5, Number 6

The Ohio State University

New instruments gauge weather

The advent of the TV weatherperson, with animated charts of high and low pressure systems and approaching thunder storms, has made looking at big weather changes a familiar experience for the average viewer.

But looking at weather and climate in miniature is a pursuit of professionals in many fields interested in measuring exactly man's meteorological environment.

New microclimatological equipment is making the job easier, faster, and more precise. The equipment recently acquired by the Department of Geography has also enabled Ohio State to set up one of the best climatology programs in the country, Dr. John N. Rayner, chairman, said.

Probably no other Geography Department has such-up-to-date equipment, he said, and certainly no other uses such instruments for teaching.

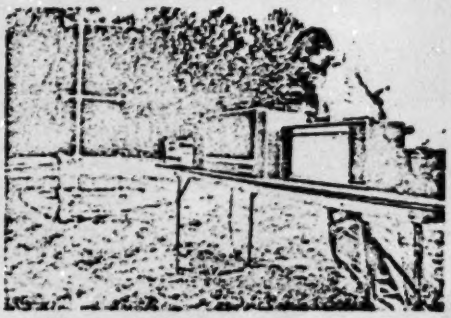
"The hands-on experience is very valuable for students," Dr. John Arnfield, assistant professor of geography, said.

The new tools, with which atmosphere energy exchanges may be evaluated, will be used by graduate students and faculty members in their research and for teaching an undergraduate/graduate level class, "Microclimatological Measurements."

The miniature anemometers measure wind speed at various levels, which

may range from zero on the ground to large values a few meters above the ground level. "We are not so much interested in actual wind speeds at various levels as with using this information to measure turbulent energy exchanges," Dr. Arnfield said.

The Bowen Ratio Mast senses simultaneously the temperature and



moisture. "With the measurements from these instruments," Dr. Rayner said, "we can estimate, for example, evaporation from the surface. This could have practical use for irrigation, because equipment could be set up in one location and the water needs for a larger area could be estimated."

This instrument generates a lot of data which feeds onto a magnetic tape

for computer analysis, thus saving untold hours of transcribing measurements. Another advantage is that it is versatile, and a number of students can be working on different projects at the same time.

The pyranometer measures solar radiation directly from the sun and from reflections. Its combined measurements of direct rays with indirect or diffuse radiation can go directly onto magnetic tape.

The net pyrradiometer measures the total amount of radiation that a given surface absorbs. Different surfaces such as grass, a field of beans,

a parking lot, or a lake retain varying amounts of radiant energy, so the climate of air above them is different.

This instrument measures both the radiation coming in and that going out. It can also be moved around over various surfaces to evaluate the amount of energy retained by each.

The instrument on the left in the above picture puts a series of 15 measurements on magnetic tape directly usable by computer.

The new instruments were purchased through a $12,000 grant by the College of Social and Behavioral Sciences.

—

APPENDIX B

PROGRESS REPORT

TO

NATIONAL SCIENCE FOUNDATION

FOR

NSF GRANT NO. GZ-1369

UW ACCT NO. 144-9944

COURSE IN BIOMETEOROLOGICAL FIELD TECHNIQUES

Report Period: 30 September 1974 through 30 November 1975
Report Completed - November 1975

During the Fall of 1974, the mobile laboratory was located at the University of Ohio, Columbus, to facilitate an environmental techniques course. A summary of the use is given below.

As reported last year, we had inquiries from several locations regarding the use of the mobile laboratory for the summer of 1975. Minnesota in 1973 had reserved the laboratory for 1975, but Dr. Robert Maxwell, who had developed the biometeorological field techniques programs at the Itasca Biological Station, moved from the University of Minnesota to Sigund-Olsen Institute, Northland College, very late in 1974 and other staff were unprepared to offer the program. The Douglas Lake Biological Station wanted the mobile laboratory to provide equipment for graduate thesis research, and the University of Wisconsin-Green Bay requested its use for instruction of a summer course. We reserved the mobile laboratory for the instruction at UW-Green Bay, but the course was cancelled in late May.

Because of the above cancellations, the mobile laboratory was not used in formal summer field course instruction during 1975. However, the equipment was used in graduate training and research by three groups of students at the University of Wisconsin-Madison. Plant-water potential, stomatal resistance, and radiation equipment was used continuously for four months by an interdepartment group of three graduate students from the Departments of Horticulture and Soil Science; humidity instruments were used continuously for about six weeks by two students in Agronomy; and wind equipment was used for over four months by two students in Entomology. This use was comparable to that proposed at Douglas Lake.

University of Ohio

The mobile laboratory was used on the Columbus Campus as the focus for a formal course developed about the laboratory. The pertinent data are given below.

Course

Geography 694. Microclimate measurements: (5 hours credit, quarter system); Professors John N. Raynor and John A. Arnfield, Department of Geography, shared the instruction responsibility.

The course was designed to introduce students with biological and physical interests to the theory and practice of measurement with emphasis upon the microclimate area. The class met each week of the ten-week quarter for 3 hours of formal lecture and 3 hours for practical work. In addition, during the last two weeks and during an eleventh week, the students worked on individual projects using various items of the equipment.

The topics discussed included instrument response; sampling (spatial and temporal); calibration; simple electrical principles; measurements of temperature, radiation, humidity, wind; turbulent transfer; heat balance.

Students

Twelve students participated; five were in Ph.D. programs, 3 were in M.S. programs and four were undergraduates. Of these, seven were in geography, three in biological fields, and two in engineering and physics.

Financing

Ohio paid for insurance on the equipment in the mobile laboratory. Transportation and part of the maintenance costs were met by the NSF grant. Other maintenance costs were met by the University of Wisconsin.

Equipment duty

Equipment was used for a total of 1560 student hours, as outlined below by category. During any hour under a category, 1 to 6 particular items may have been used, and usually more than six meters, recorders, or power supplies were used.

Equipment category	Student hours: Formal course	Student hours: Individual
Meters, recorders, power supplies	720	130
Temperature	220	55
Radiation	145	50
Humidity	145	5
Wind	70	20
	1300	260